QUALITY OF SPINAL EXTRADURAL ANAESTHESIA: THE INFLUENCE OF SPINAL NERVE ROOT DIAMETER

A. GALINDO, J. HERNANDEZ, O. BENAVIDES, S. ORTEGON DE MUNOZ AND J. J. BONICA

SUMMARY
Profiles on the progress of spinal extradural anaesthesia were made in 246 patients using various concentrations of lignocaine, bupivacaine and etidocaine. The advance of analgesia through the different dermatomes showed a consistent and orderly spread on the upper lumbar and thoracic segments. This spread was irregular through the lower lumbar and upper sacral segments. The first sacral segment was especially difficult to block with an overall failure rate of 17.53% with presently available concentrations of various local anaesthetics. This failure was abolished with the use of etidocaine 1.5%. The presence of a delay or failure at the level of L5–S2 is probably related to the larger diameter of these nerve roots as ascertained from measurements in 11 cadavers.

Several factors have been considered to influence the quality and extent of anaesthesia induced by administering local anaesthetics into the spinal extradural space (Bromage et al., 1964; Burn, Guyer and Langdon, 1973). Of these, the diameter of nerve fibres appears to determine the speed and extent at which various nerve functions are impaired (Rud Jørgen, 1961). However, the diameter of the spinal nerve roots, where individual nerve fibres are contained, has not been considered as one of the factors determining the rate and degree of penetration of these anaesthetics. The purpose of this study was to analyse the influence of the nerve root diameter on the quality of neural blockade during extradural anaesthesia.

METHODS
Observations were made on the latency, spread, and duration of extradural anaesthesia after the injection of etidocaine 1% and 1.5% (Duranest or Astra W 19053), bupivacaine (Marcain) 0.5% and lignocaine (Xylocaine) 1.5 and 2% into the spinal extradural space. All solutions contained adrenaline 1:200,000. For comparison additional observations were made during the progress of subarachnoid block achieved with 5–15 mg of amethocaine (Pontocaine).

Spinal extradural anaesthesia was chosen on the basis of the type of operation, clinical indications, and a thorough discussion with the patient on the various aspects of this technique. Patients in whom the new anaesthetic drug, etidocaine, was administered were informed and agreed to its use.

Table I summarizes the characteristics of the 246 patients in whom those observations were made. Since this report is concerned with the spread of anaesthesia to the lumbar and sacral segments, information not related to this subject has been omitted.

Patients were instructed in the procedure and technique to be applied and the method of testing the various sensory modalities to follow the progress of the anaesthetic blockade. Premedication was limited to not more than diazepam (Valium) 10 mg 1 to 2 hours before operation. Extradural puncture was performed using either the paramedian or medial approach with a 16-gauge Tuohy needle and the loss of resistance technique to identify the extradural space (Bonica, 1967). A polyethylene catheter was advanced, either cephalad or caudad, for 3 cm beyond the tip of the needle and the needle was withdrawn. Two ml of the anaesthetic solution was injected as a test dose 3 min before

A. GALINDO, M.D., PH.D., Department of Anesthesiology, University of Washington School of Medicine, Seattle, Washington 98195 and Instituto Neurologico de Colombia, Bogota, Colombia; J. HERNANDEZ, M.D., O. BENAVIDES, M.D., S. ORTEGON DE MUNOZ, M.D., University Hospital, Escuela de Medicina Universidad del Rosario, Bogota, Colombia; J. J. BONICA, M.D., Department of Anesthesiology and Anesthesia Research Center, University of Washington School of Medicine, Seattle, Washington 98195.
the injection of the therapeutic dose which varied according to the operation and the desired extent of block.

Figure 1 is a schematic diagram used to identify various dermatomes. Pinprick was used to determine the degree and extent of sensory blockade. The onset of block was timed when the patient felt the pinprick as less painful, "hypoalgesia", than in the unblocked part. Analgesia was considered to be present when the patient stated positively that he or she felt "pressure but no pain". The sensory input from the skin covering the external two-thirds of the sole was considered a purer representation of S1. Owing to the embryologic development, skin analgesia can be delineated more accurately in S1 than in other spinal nerve roots, where overlapping becomes a limitation (Last, 1972).

Complete thoracic, lumbar, and sacral laminectomy was performed in 11 cadavers varying in age from newborn to 80 years. The spinal cord and its nerve roots were observed and photographed in situ and then taken for gross measurements and further photographs before and after the opening of the dura. These spinal cords were fixed in formalin; the nerve roots, properly identified, were cut with their dural sleeve intact and then processed for myelin and nerve axon stain and mounted in glass plates. From these plates, measurements of nerve root diameters were made and the proportion of connective tissue to nervous tissue ascertained.

RESULTS
Failure to block completely the response of S1 to pinprick stimulation occurred in 17.53% of all patients who received extradural block, except for those patients who received etidocaine 1.5%. The
occurrence of this failure, an example of which is illustrated in figure 2, was established only when the lower three sacral segments had been completely anaesthetized; lack of anaesthesia in all sacral segments was interpreted as a failure of vertical spread of the anaesthetic solution rather than poor penetration into the spinal roots. The incidence of failures to block S1 was greater in younger patients (table II). In general, S1 took longer, and was more difficult to block than any other spinal root (fig. 3 and table II). In those patients in whom an effort was made to block S1, by directing the catheter to this root and fractioning the dose of the anaesthetic, this root was the last to be blocked and the last to recover from anaesthesia (fig. 4). Nerve roots S2, L5 and L4 were also difficult to block, though less so than S1.

The delay in blocking the last two lumbar and first two sacral segments, especially S1, was so common with all anaesthetics, at all concentrations, and with both extradural and subarachnoid anaesthesia, that its absence in the profile, commonly seen during lateralization of anaesthesia or abnormally long onset time of the block, was a reasonable indication of technical failure.

Complaints in the form of "deep pain", "burning", or "vague uneasiness" during the course of the operation were greater when S1 and/or S2 had taken more time to be blocked or the patient maintained some awareness to pinprick in this area throughout the procedure (failure). Complete block of S1 also took longer than block of the last three sacral segments during the establishment of subarachnoid anaesthesia (table II).

During anaesthesia with etidocaine 1.5%, there was no failure to block S1 in any of the 40 patients. The latency for blocking this segment was 14.3 min compared to 7.2 min for the last three sacral segments (table II). In association with this fast blockade of S1, the quality of anaesthesia and motor blockade was excellent. There were fewer complaints from the patients when etidocaine 1.5% was used for extradural anaesthesia as compared with the other agents and concentrations.

Table III presents the average spinal root

![Figure 2. Example of a graph representing the extent and speed at which the various spinal nerve roots were blocked in a representative patient. The vertical axis indicates the segments. T=thoracic, L=lumbar and S=sacral. The site of penetration and probable location of the extradural catheter is represented by the small tube on the left of the diagram. Time on the horizontal axis has three different scales. Eight ml of etidocaine 1% with adrenaline 1:200,000 were given at time 0; onset of anaesthesia took 3 min and reached stable conditions within 12 min. S1 and S2 nerve roots were not completely blocked, but there was "hypoalgesia" to pinprick. At (1) the cremasteric and anal reflexes were abolished. Surgery (- - -), repair of left inguinal hernia, was performed under satisfactory anaesthesia; the patient complained of some "vague pain" during heavy manipulation of the operative field.](image-url)
FIG. 3. Profile of extradural anaesthesia similar to figure 2. Thirteen ml of bupivacaine 0.5% with 1:200,000 adrenaline were given at time 0; they were preceded (3 min) by 2 ml of the same anaesthetic solution used as a test dose. (1) Cremasteric and anal reflexes abolished. (2) Motor function impaired more than 80%. Surgery (---), repair of varicocele, was performed under satisfactory anaesthesia; however, S1 was not completely blocked during the surgical period.

FIG. 4. Profile of extradural anaesthesia similar to figure 2. The extradural catheter was directed caudad and the initial dose of the anaesthetic was divided into two parts. Seven ml of etidocaine 1% with adrenaline 1:200,000 were given at time 0; an additional 8 ml of the same solution was given 10 min later. The lower sacral segments (S3–S5) were blocked before L4 and L5 and S1–S2. S1 was the last segment to be anaesthetized and also the last to recover. Surgery (---), vaginal hysterectomy, was performed under satisfactory anaesthesia.

diameter of the sacral roots in six cadavers, ages 12 to 80 years, and table IV shows the diameters of S1 in relation to age. There were no significant differences in root diameter beyond 20 years of age, but the proportion of connective tissue increased with age (fig. 5).

DISCUSSION

These clinical observations indicate that the delay or failure to block S1 during the administration of commonly used concentrations of local anaesthetics into the spinal extradural space occurs in approximately 20% of all patients. This failure seems to account for the so-called "spotty anaesthesia" and appears related to the large diameter of S1. Previous observations have shown some delays in the blockade of L5 and S1 (Bromage, 1969), but no systematic study of this phenomenon has been undertaken, nor has it been related to the diameter of the spinal nerve roots. This lack of information has probably resulted from the fact that the skin distribution of S1, located in the external two-thirds of the sole of the foot, is an infrequently tested area. Despite being a small area its blockade is important because the nerve fibres to this region are expected to be located in the centre of S1.

Consideration of the embryology shows that the first sacral segment is the central point from which the nervous system invaginates to form the innervation of the lower limb, turning S1 into the largest spinal nerve root, followed by S2 and L5 (Last, 1972). S1 is approximately five times larger than S5 and twice as large as the lower six thoracic and first two lumbar spinal nerve roots. The large diameters of these roots seem to determine the slow penetration of anaesthetics through L5, S1 and S2 as shown by the consistently slower spread.
Fig. 5. Light microscopy of sections (×78) of S1 obtained from a newborn (A) and an 80-year-old (B) cadaver. Note the great increase of connective tissue in the 80-year-old S1 root.
of analgesia to pinprick in areas covered by them. Recently, it has been pointed out that in patients in the prone position the spread of solutions within the extradural space is poor below L5 (Burn, Guyer and Langdon, 1973). Since patients in our study were all injected while in the supine position and the lower sacral segments were invariably blocked, Burn's studies cannot explain the failure to block S1; however, they are consistent with the idea that physical spread is not the most important factor determining the quality of neural blockade. Bromage (1962) has shown the importance of age in the neural blockade since less anaesthetic is needed in older than in younger patients to induce the same degree of extradural anaesthesia. This reduced need may be related to less lateral spread (escape) of the solutions from the extradural space (Burn, Guyer and Langdon, 1973). A decrease in the number of nerve fibres in favour of more connective tissue, as found in this study, may also contribute to this phenomenon in older patients. Furthermore, the non-neural tissue could act as a depot for the anaesthetic solution which prolongs the blocking effects of these drugs, especially with the newer more lipid soluble anaesthetics bupivacaine and etidocaine. The slow onset and longer duration of the blockade of S1 supports this suggestion.

There was a good relationship between the failure to block completely the larger spinal nerve roots and some visceral pain and other vague complaints made by patients during "spotty extradural anaesthesia". On the basis of this one may speculate that these large roots are involved in this type of sensory input or that their lack of blockade is indicative of poor penetration into other roots also. Therefore, in addition to other factors, the diameter of the spinal nerve roots should be considered when determining concentration, volume, and site of administration of local anaesthetics into the spinal extradural space.

Increasing the concentration of the anaesthetic improves the quality of the block as shown with etidocaine and to a lesser degree with lignocaine. However, a higher concentration of the anaesthetic increases the risk of systemic toxicity, a fact well known with presently available compounds. Whether this would occur with etidocaine in a larger number of patients remains to be seen. Although no toxic effects were observed in the present study the number of observations was relatively small. Injection of patients with 1.5% etidocaine, preceded always by a test dose of 20-30 mg, should be made with caution in young individuals in whom block of the large roots is indicated.

In selecting from the various drugs and concentrations at present available the anaesthetist should have in mind the age of the patient, the approximate diameter of the nerve innervating the site of the operation, and the duration of surgery. In older patients, and/or when the surgery is in areas innervated by small roots, for example the perineal region, a lower anaesthetic concentration will suffice. The real test for extradural anaesthesia is the young male patient, 18 to 30 years old, in whom knee or foot surgery is planned. At present such a patient is better off with a subarachnoid block. However, 1.5% etidocaine appears to provide an excellent extradural blockade for surgical anaesthesia and immediate postoperative pain relief.

REFERENCES

L'ANESTHESIE PERIDURALE ET LE DIAMETRE DES NERFS

RESUME
On a réalisé des études concernant la progression de l'anesthésie extradurale rachidienne dans 246 patients avec diverses concentrations de lignocaine, de bupivacaine et d'étidocaine. La progression de l'analgésie à travers les différents dermatomes manifestait une répartition uniforme et régulière sur les segments lombaires supérieurs et thoraciques. Cette répartition était irrégulière dans les segments lombaires inférieurs et sacrés supérieurs. Le premier segment sacré est particulièrement difficile à bloquer, le taux d'échec global étant de 17,53% avec les concentrations disponibles actuellement de divers anesthésiques locaux. Cet échec s'est trouvé éliminé grâce à l'emploi de l'étidocaine à 1,5%. L'existence d'un retard ou d'un échec au niveau de L5-S2 est probablement lié au fait que le diamètre de ces nerfs à la racine est plus important comme les mesures prises sur 11 cadavres ont permis de l'établir.
ZUSAMMENFASSUNG

ANESTESIA PERIDURAL Y DIAMETRO DE NERVIO
Se hicieron perfiles sobre el progreso de la raquianestesia extradural en 246 pacientes, empleando diferentes concentaciones de lignocaina, bupivacaina y etidocaina. El avance de la anestesia por los diferentes dermatomas mostró una difusión consistente metodica en los segmentos lumbar y torácico superiores. Esta difusión resultó irregular a través de los segmentos lumbar inferior y sacro superior. El primer segmento sacro fue especialmente difícil de bloquear, con una proporción total de fracasos del 17,53% con concentraciones de diferentes anestésicos locales de que se dispone en la actualidad. Se suprimió este fallo utilizando etidocaina del 1,5%. La presencia de un retraso o fallo al nivel de L5-S2 está relacionada, posiblemente, con el mayor diámetro de estas raíces nerviosas, como se ha comprobado al realizar mediciones en 11 cadáveres.